EXECUTIVE SUMMARY

ITS Impacts Assessment for Seattle MMDI Evaluation: Modeling Methodology and Results

September 1999

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James A. Bunch
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Contract Sponsor: Federal Highway Administration
Contract No.: DTFH61-95-C00040
Project No.: 099818E3-0A
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MITRETEK SYSTEMS
McLean, Virginia

FINAL REPORT

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ACKNOWLEGEMENTS

The authors wish to acknowledge numerous colleagues for their contributions to this study.

On the MMDI evaluation team: Joe Peters, the sponsor of this work at the Joint Program Office, for his comments and support; Jane Lappin (EG&G Dynatrend/Volpe) and Chris Cluett (Battelle) for insights and data on travel behavior and ATIS usage rates; Michel Van Aerde, Hesham Rakha and the researchers at the Virginia Tech Center for Transportation Research in the area of energy, emissions and safety modeling; and Mark Carter (SAIC) for his comments on numerous draft documents.

On the Smart Trek team in Seattle: Bart Cima (IBI Group), Peter Briglia (Washington State DOT), Mike Forbis (WSDOT) and Mike Swires (WSDOT).

Colleagues at Mitretek who contributed to the study: Will Litton, Warren Marquez, Donald Roberts, Allen Proper, Raja Sengupta, Vaishali Shah, Michael McGurrin, Richard Glassco, Art Salwin and Melvyn Cheslow.

ABSTRACT

At the request of the Joint Program Office (JPO) for Intelligent Transportation Systems (ITS) of the Federal Highway Administration (FHWA), Mitretek Systems has conducted a modeling analysis of ITS impacts in support of the Metropolitan Model Deployment Initiative (MMDI) evaluation program. The Mitretek modeling effort supports the evaluation of the Seattle model deployment, Smart Trek, through impact analysis in the areas of Advanced Traveler Information Services (ATIS), Advanced Traffic Management Systems (ATMS), and Incident Management Systems (IMS). Of particular interest to this modeling study (as well as the overall MMDI effort) is the quantification of likely impacts from data sharing or integrated control between functional areas (ATIS, ATMS, and IMS) and across jurisdictions. This document presents the methodology of the study and details findings for a mixed freeway/arterial corridor model drawn from the roadway network north of downtown Seattle. Impacts are characterized in terms of near-term peak period delay reduction, travel time reliability, changes in regional mode choice, corridor travel throughput, fuel consumption, emission rates, and other measures.

KEYWORDS: Intelligent Transportation Systems, Federal Highway Administration, benefits, modeling, simulation, Advanced Traveler Information systems, Advanced Traffic Management Systems, Metropolitan Model Deployment, evaluation, Smart Trek.

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At the request of the Joint Program Office (JPO) for Intelligent Transportation Systems (ITS) of the Federal Highway Administration (FHWA), Mitretek Systems has conducted a modeling analysis of ITS impacts in support of the Metropolitan Model Deployment Initiative (MMDI) evaluation program. The Mitretek modeling effort supports the evaluation of the Seattle model deployment, Smart Trek, through impact analysis in the areas of Advanced Traveler Information Services (ATIS), Advanced Traffic Management Systems (ATMS), and Incident Management Systems (IMS). Of particular interest to this modeling study (as well as the overall MMDI effort) is the quantification of likely impacts from data sharing or integrated control between functional areas (ATIS, ATMS, and IMS) and across jurisdictions. This document presents the methodology of the study and details findings for a mixed freeway/arterial corridor model drawn from the roadway network north of downtown Seattle. Impacts are characterized in terms of near-term peak period delay reduction, travel time reliability, changes in regional mode choice, corridor travel throughput, fuel consumption, emission rates, and other measures.

Background

Mitretek, in the JPO-sponsored study "Incorporating ITS into the Planning Process" predating the MMDI effort [2], developed an evaluation methodology and a set of network models of Seattle suitable for the assessment of ITS impacts at a subarea and regional level. When the MMDI evaluation program began, MMDI team leaders recognized that leveraging existing Mitretek modeling resources was a logical and efficient option in support of Smart Trek evaluation, especially given the long lead times and expense associated with large-scale simulation network development and calibration.

The previous Mitretek modeling study projected localized and regional impacts in the year 2020 from a range of potential transportation system improvements within a 120-square mile freeway/arterial corridor north of the Seattle central business district (Figure ES-1). However, the 2020 forecast year models and data sets were not constructed with MMDI projects in mind, and Mitretek had to modify and re-calibrate them to reflect the near-term MMDI evaluation effort. New travel demand was estimated for the North Corridor model based on a forecast for the 1997/1998 evaluation time frame. Calibration of the network for MMDI evaluation included a flow analysis as well as a calibration of within-peak travel time variation and day-to-day reliability of freeway travel.

The area represented by the North Corridor model features a highly utilized multi-modal transportation system, with significant travel delays during both the morning and evening peak travel demand period. Many of the ITS enhancements associated with the MMDI evaluation effort are planned or operational within the North Corridor; however, some are deployed outside the subarea and cannot be assessed with the North Corridor modeling system. Altogether, Mitretek modeling analysis in the North Corridor provides direct evaluation support to 13 of 26 projects in Seattle selected for evaluation as a part of MMDI ranging from ATIS provision, traffic signal control improvements, and incident management enhancements.

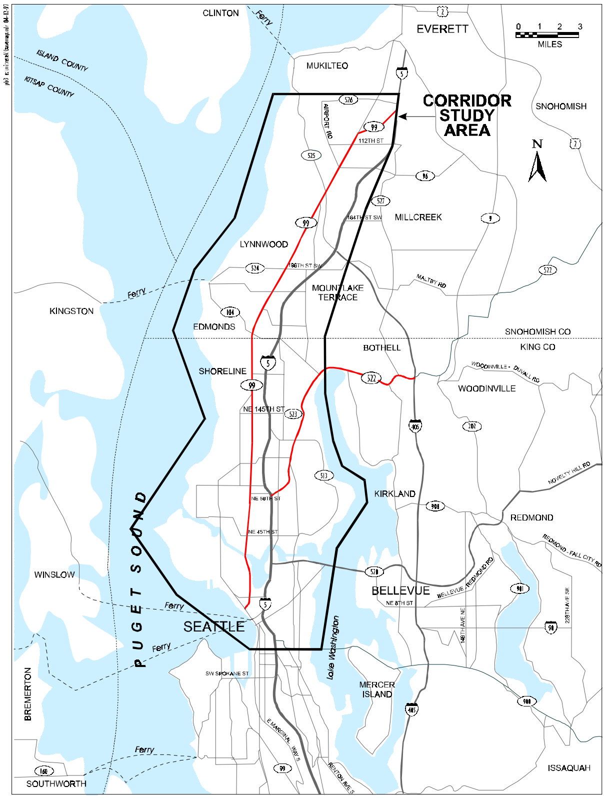

Figure ES-1. The Seattle North Corridor Study Area

Role of Modeling

The Mitretek modeling analysis effort for MMDI has focused on project features that are difficult to evaluate with direct field measurement. For example, during the evaluation period, overall travel demand rose concurrently with overall utilization of web-based ATIS. Differentiating these impacts would be problematic at best using the existing data collection methods in the Seattle area (primarily loop detectors). In cases like this, models are helpful in systematically and independently quantifying the impacts of concurrent factors such as rising travel demand or web-based ATIS usage.

Likewise, the modeling effort also assists local MMDI partners in projective analyses of interest regarding specific projects. For example, MMDI-related improvements in arterial data collection and archiving facilitate the development of coordinated inter-jurisdictional traffic signal plans along major arterial corridors. However, participating jurisdictions are reluctant to implement these plans until impacts to both local and through traffic can be estimated. In cases such as these, models are helpful in providing insight before a commitment to full implementation is made.

The focus of the modeling and simulation work is a reflection of the role it plays in supporting both national MMDI evaluation goals and the goals of the local Smart Trek participants. In support of the national evaluation, for example, the modeling work seeks to quantify relationships between rising ATIS market penetration and measures of overall system impacts such as throughput or energy consumption. Likewise, some experiments address more specific hypotheses of local interest. For example, in the traffic signal case discussed above, that integrated data collection, archiving and cross-jurisdictional cooperation have positive impacts on network efficiency both along and within the arterial corridor. In order to meet these goals, the intent of the Mitretek modeling effort is not to explicitly evaluate the impact of each MMDI project, although where such impacts can be reliably estimated these impacts will be highlighted. Rather, the focus is on testing hypotheses related to national or local goals, and on benchmarking impacts in Seattle from the deployment of newly integrated ITS capabilities in the MMDI time-frame.

Summary of Evaluation Approach

Mitretek has developed an ITS evaluation methodology, the Process for Regional Understanding and EValuation of Integrated ITS Networks (PRUEVIIN). It features a traditional four-step transportation planning model as well as a traffic simulation to capture regional and corridor-level ITS impacts. For this study, EMME/2 is implemented as the transportation planning model and INTEGRATION 1.5 is implemented as the simulation model. Transportation planning analyses typically deal with various infrastructure deployment plans or alternatives to meet forecast transportation needs for a particular corridor.

The performance of each alternative is evaluated using a combination of a planning model and a simulation. The regional planning model is employed to identify impacts on travel demand including trip distribution, mode choice and regional assignment. The regional travel demand model represents long-term adaptation by the travelers in the system to average conditions experienced in the peak period.

Measuring ITS impacts over a range of conditions is a key element in accurately calculating annualized impacts. As depicted in Figure ES-2, impacts analysis is often conducted under "normal" conditions: an assumption of invariant average travel demand, clear weather and no accidents in the roadway system. However, the reality of the urban travel is quite different from this notion of normality. In fact, ITS typically has a greater impact when unusual conditions prevail, i.e., snow, special events, and major incidents. Particular types of ITS enhancements may be beneficial in very different situations. Accounting for these ITS impacts under various conditions is critical for an accurate evaluation, as is identifying the relative frequency of each event.

Accordingly, the simulation is exercised through a series of 30 scenarios. Each scenario represents a particular combination of weather impacts, travel demand variation, as well as a pattern of incidents and accidents in the corridor. The scenarios were derived from a cluster analysis of traffic flow data (for variations in day-to-day travel demand) and weather/incident impacts (taken from historical archives). Each scenario has a probability of occurrence. The scenarios taken together comprise a representative year of operation. The use of representative day scenarios within the PRUEVIIN framework facilitates the analysis of system variability for ITS evaluation.

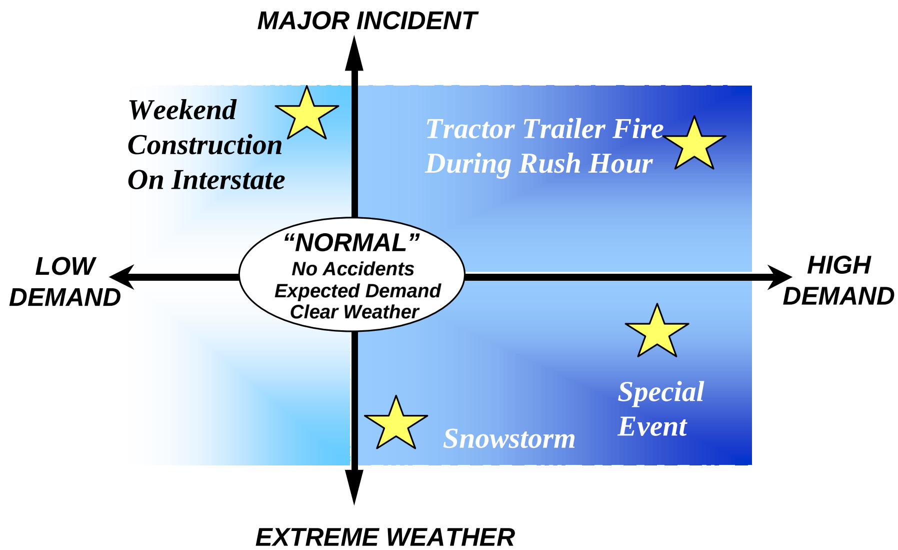

Figure ES-2. Potential Range of Conditions for ITS Evaluation

Simulation analysis over the representative year of operation allows for a meaningful linkage between the two modeling scales. Travel time impacts by scenario can be rolled into an annual average and compared with baseline travel in the regional model. These differences can then be analyzed to examine potential shifts in regional demand patterns. Examples of changes to trip patterns include changes in trip length, mode split, and shifting of demand between parallel corridors.

Evaluation of ITS Enhancements: Project Groupings

Project groupings are used to identify Smart Trek projects that utilize the same kinds of technologies or integrate similar traffic control components. Hypothesis are tested and impacts reported by project groupings, not by individual project. In some cases, projects are grouped because the impact of a single project acting in isolation has either no impact or an impact that cannot be measured in modeling. For example, the On-Scene Incident Video project alone has no impact unless it is coordinated through the WSDOT Northwest Region Transportation Management Center and linked to more effective incident management. In this case it is only natural to consider projects together when they support a particular ITS component or user service. Four project groupings are used here for the evaluation of ITS enhancements: ATIS, ATMS, IMS and Integration (enabling a range of potential integrated deployments between the ATIS and ATMS project groupings).

The ATMS grouping includes projects that serve to archive and consolidate arterial traffic data from a number of sources in a central location. The ATIS project grouping comprises a collection of pre-trip and en route information services presenting current congestion conditions based on real-time Washington State Department of Transportation (WSDOT) freeway detector data. The IMS grouping is composed of projects that (among other goals) seek to improve detection, response time, and freeway system efficiency under incident conditions. The Integration grouping contains only one project, ITS Backbone, which allows for data collected from arterial sensors for the purpose of traffic signal control to be utilized in support of ATIS. First, this cross-functional data sharing capability is evaluated with respect to improved ATIS real-time coverage in isolation from any changes to traffic signal control. Second, a cross-functional (ATIS/ATMS) integrated deployment is evaluated with concurrent improvements to traffic signal control as well as more comprehensive ATIS provision. This cross-functional deployment is called the Enhanced ITS alternative. The Enhanced ITS alternative is evaluated using both the regional and corridor simulation models to evaluate the potential “big-picture” impact of integrated ITS deployment on regional travel. All other analyses, or sensitivity analyses for ATIS, ATMS, and IMS stand-alone deployments are conducted within the simulation model alone. An overview of the experimental plan for this study is presented in Figure ES-3.

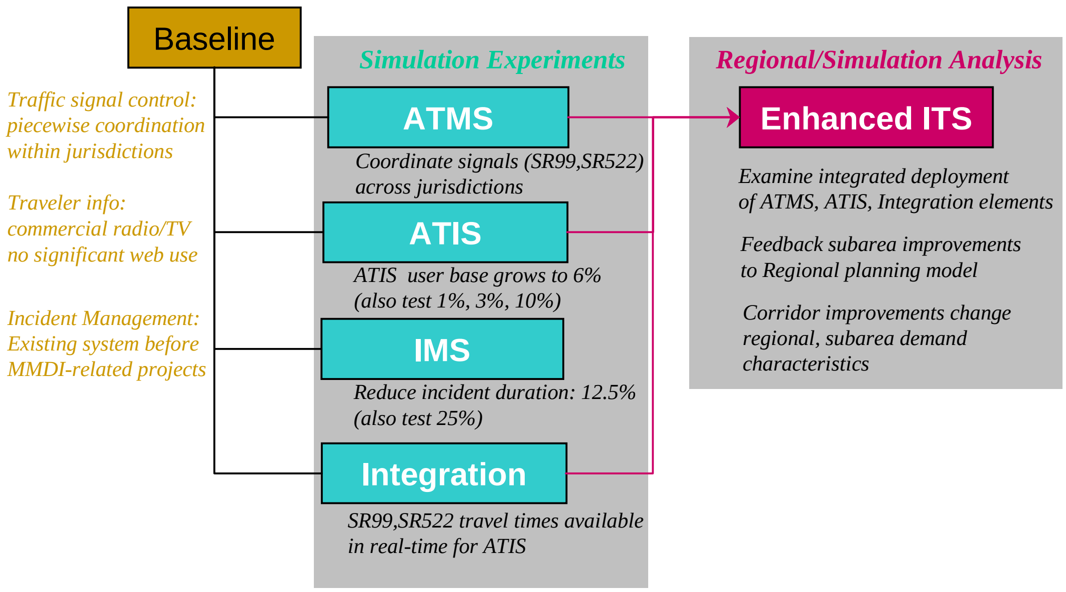

Figure ES-3. Experimental Overview

Measures of Effectiveness

Results are reported by project grouping. Each experiment is described in terms of hypothesis, experimental controls, network efficiency impacts (delay reduction and throughput), as well as energy and emissions impacts. Each experiment is compared with a uniform Baseline case; representing long-standing traveler information services and traffic management systems deployed in the corridor. For example, commercial traffic reporting and ramp metering control on I-5 are considered to be elements of the Baseline case.

<u>Subarea Impact Measures</u>: For network efficiency impacts, data is collected for all vehicles that begin trips in the network between 6:15 AM and 9:00 AM in the North Corridor. For these trips, average delay is calculated as the difference between the average travel time in each scenario and free-flow (50% of average demand, no accidents in the system, good weather) travel times. *Delay reduction* is calculated by expressing the difference in average delay between the Baseline case and the experimental case as a percentage of Baseline average delay. *Throughput* measures the number trips starting in the 6:15-9:00 time frame that can finish before the end of the peak period at 9:30 AM. Delay reduction and throughput measures are calculated for each scenario. An annualized figure is then calculated by computing a weighted average of across all scenarios. System *coefficient of variation* is calculated by examining the variability of travel time for

similar trips in the system taken across all scenarios. This statistic is an indicator of the reliability of travel time in the corridor.

Speed and stops across the network are archived by link in each run of the simulation between 6:00 AM and 9:30 AM. Speed profiles are then normalized by total vehicle-kilometers of travel in the system to create the statistic *percentage of vehicle-kilometers of travel by speed range*. A similar technique is applied to stops estimated by the simulation at a link level. The *expected number of stops per vehicle-kilometer of travel* is the measure used in comparison with the Baseline case.

Link-level speed and stop data are used to drive an energy and emissions post-processor developed for MMDI evaluation at the Virginia Polytechnic Institute and State University [3]. Energy estimates are calculated *as total liters of fuel consumed*. Total emissions of *hydrocarbons* (HC), *carbon monoxide* (CO) and *nitrates of oxygen* (NOx) are also estimated. A related safety post-processor [4] utilizes total vehicle-kilometers and total vehicle-seconds of travel by speed range reported by the simulation to predict *total crashes* and *total fatal crashes*.

Subarea measures of effectiveness are obtained from simulation model runs. A paired t-test analysis is performed on each measure to determine the relative level of statistical significance of the results against inherent randomness in the simulation.

<u>Regional Impact Measures</u>: Regional impact measures are obtained from the regional four-step planning model runs. The impacts of corridor improvements on regional travel demand patterns are reported in terms of *transit mode share*, *auto mode share*, *trip length* and *trip speed*. Similar measures are also used to characterize travel demand originating in or traveling to or through the North Corridor. Additional travel demand attracted to the corridor because of improved performance is reported as *additional corridor demand*. Regional impact measures are only reported in the Enhanced ITS Alternatives Analysis.

ATIS Experiment: Hypothesis, Controls and Findings

<u>Hypothesis:</u> At an estimated near-term rate of ATIS usage, the provision of primarily pre-trip traveler information services containing more accurate, frequently updated quantitative freeway travel time estimates reduces overall travel delay and variability, improves system throughput, and reduces the total number of vehicle-stops.

<u>Experimental Controls:</u> The ATIS experiment attempts to capture current and projected near-term impacts on the North Corridor from the rising utilization of various traveler information services. MMDI projects represented in the ATIS experiment include Microsoft Sidewalk Traveler Information, Etak/Metro Traffic Control Traveler Information, Fastline Hand-held PC, Traffic Channel on Cable TV, WSDOT Web Page and Traffic Telephone Information Line. The simulation modeling used to evaluate ATIS impacts cannot differentiate between media employed to deliver similar messages at the same decision point in the trip. However, the model can discriminate based on whether the information is provided pre-trip or en route, the coverage area, and the level of message detail. An example of message detail is the difference between a variable message sign indicating “congestion ahead” versus a detailed quantitative assessment of

delay with precise location ("current travel time for I-5 is 12.5 minutes between exit 3 and exit 4").

Traveler information services in the baseline case provide incident, construction, and other emergency road closure information on radio, TV, variable message signs and highway advisory radio, as they have been in Seattle for many years. In the ATIS case, visual displays of I-5 freeway travel congestion throughout the system are available, thereby allowing the traveler to more effectively gauge likely travel time for an intended trip. In the baseline case, route choice decisions are made under greater uncertainty about the delays associated with incidents, weather or recurrent bottlenecks. In the ATIS case, travel choices are made with lesser uncertainty because a current estimate of travel time is provided to the user. PSRC panel survey data (1997) indicates that 16% of travelers hear traffic reports pre-trip, primarily through commercial media. The assumption tested in this experiment is that pre-trip information users migrate to the collection of higher fidelity ATIS pre-trip services represented by the MMDI projects listed above. An overall higher-fidelity ATIS usage rate of 6% is used for this experiment (roughly 1 out of every three pre-trip information users) based on the extrapolation of PSRC panel survey rates and the website user session growth since the time of the survey. Since there is a great deal of uncertainty about this figure, a sensitivity analysis around the 6% figure is also conducted, included in the full report but not discussed here.

Table ES-1. System Efficiency Impacts, ATIS Experiment

Measure per Average AM Peak Period, North Corridor Subarea	Baseline	ATIS	Change	% Change
Vehicle-Hours of Delay	17,879	17,619	-260	-1.5%
Vehicle Throughput	209,372	209,382	+10	+0.0% (NS)
Coefficient of Trip Time Variation	.242	.236	-.006	-2.5%
Vehicle-Km of Travel	3,438,000	3,436,000	-2,000	-0.1% (NS)
Total Number of Stops	1,200,000	1,201,000	+1,000	+0.1% (NS)

(NS) = not statistically significant vs. baseline at 90% confidence level

<u>Network Efficiency Impacts</u>: The ATIS experiment indicates that the improvements modeled have limited but positive annual impact on overall system performance (Table ES-1). In each AM Peak Period, total system delay for the North Corridor is reduced by 260 vehicle-hours, a 1.5% reduction. An average of 10 additional vehicles per day traverse the network, although this increase is too small to be statistically significant. Travel is more reliable as travel time variation is reduced by 2.5%.

ATIS impact is highest in scenarios with poor weather, heavy demand, freeway accidents or any combination of these factors. Eighty percent of the total delay reduction attributable to ATIS improvements is accounted for in scenarios with a combined probability of 28%.

More precise freeway congestion information is consistently helpful to certain kinds of trips in the system. These are not the long freeway-based trips usually associated with ATIS but mid-range trips (18-25 km) within the subarea that cross I-5. An example of such a trip is from Edmonds to the University of Washington southeast across the corridor. These travelers can access I-5 at several exits or bypass it altogether when choosing from a set of relatively competitive alternative routes. Users of the pre-trip information service reduce their average delay by 3.9% (vs. 0.9% for the system) and have more reliable trips than non-users.

The impact on facility speed is indeterminate in nature. The amount of travel occurring in the system with fewer than 0.25 stops per kilometer increases by roughly 9 percent. A small improvement in expected stops per kilometer can be observed for freeway travel. Stops per kilometer on non-freeway facilities do not change significantly.

Table ES-2. Energy and Emissions Impacts, ATIS Experiment

Measure per Average AM Peak Period	Baseline	ATIS	Change	% Change
Fuel Consumption (l)	354,620	354,230	-390	-0.1% (NS)
HC Emissions (kg)	390.0	389.6	-0.4	-0.1% (NS)
CO Emissions (kg)	7043	7020	-23	-0.3% (NS)
NOx Emissions (kg)	846.2	843.9	-2.3	-0.3% (NS)

(NS) = not statistically significant vs. baseline at 90% confidence level

Energy and Emissions Impacts: The ATIS experiment resulted in a small decrease in subarea travel and a small increase in total vehicle stops. These changes translate into small positive impacts on subarea energy consumption and total emissions using the Virginia Tech post-processor (Table ES-2). Viewed against the inherent randomness in the simulation, however, none of these changes can be shown to be statistically significant.

Safety Impacts: The ATIS experiment indicates a decrease in the number of crashes by 0.6%. The reduction in crashes of all types is related to an overall increase in subarea travel speeds. The post-processor employed for the safety analysis generally predicts fewer crashes at higher speeds, but the risk of these crashes being fatal increases. In this case, the overall reduction in crashes also reduces fatal crashes. The expected number of fatal crashes over a ten year period was reduced from 114.9 to 114.4, a 0.4% decrease.

ATMS Experiment: Hypothesis, Controls and Findings

Hypothesis: Improvements in arterial signal coordination along SR99 and SR522 from jurisdictional cooperation and adjusting southbound progression speed for expected average queues at intersections improves corridor throughput and efficiency.

Experimental Controls: The ATMS experiment attempts to capture impacts on the North Corridor from a prospective re-timing of signals along two major arterials. This prospective re-timing is enabled by the North Seattle ATMS project, which archives detector data collected along the arterials at the Northwest TSMC.

Current signal timing plans along the two major arterials can be characterized as fixed-timing plans optimized for peak period flow with piece-wise coordination within jurisdictions. In the case of SR99, there are four jurisdictions; along SR522 there are two. Progression along the corridors is generally set close to posted speed limits. Signal timing plans based on these assumptions were implemented in the simulation as the default baseline plan.

Three distinct effects of this prospective re-timing project are modeled in the simulation as a part of this experiment:

- The impact of coordinating signals at major intersections from “top to bottom” along SR99 and SR522 without regard to the current jurisdictional boundaries.

- The coordination of minor signals along these same corridors at variable progression speeds between major intersections.
- The calculation of progression speeds between major intersections based both on speed limit and adjustment made to offset timings based on average peak-period queue length. The adjustment for queue dispersion along SR99 and SR522 was calculated using trial-and-error optimization under average travel demand.

Table ES-3. System Efficiency Impacts, ATMS Experiment

Measure per Average AM Peak Period, North Corridor Subarea	Baseline	ATMS	Change	% Change
Vehicle-Hours of Delay	17,879	16,661	-1,218	-7.0%
Vehicle Throughput	209,372	209,774	+402	+0.2%
Coefficient of Trip Time Variation	.242	.237	-.005	-2.1%
Vehicle-Km of Travel	3,438,000	3,455,000	+17,000	+0.4%
Total Number of Stops	1,200,000	1,167,000	-33,000	-2.7%

<u>Network Efficiency Impacts</u>: The ATMS experiment indicates that the improvements modeled have a measurable impact on overall system performance (Table ES-3). Total system delay for the North Corridor is reduced by 1,218 vehicle-hours in the AM peak period, a 7.0% annualized reduction. An average of 402 additional vehicles per peak period traverse the network, a 0.2% increase. Travel is slightly more reliable as travel time variation is reduced by 2.1%.

The impact of signal re-timing is broadly distributed over a range of scenarios. Eighty percent of the total delay reduction attributable to ATMS improvements is accounted for in scenarios with a combined probability of 67%. Highest delay reduction is realized in scenarios where the ratio of travel demand to network capacity is close to expectation. That high performance is located close to expectation is not surprising, given that the signal timing plans have been optimized for this condition. Improved performance is not seen in all scenarios, however, including some cases of marginally reduced throughput and increased delay. These negative impact cases occur in extreme high demand scenarios or in snow conditions, indicating that the signal timing plans optimized for average conditions may be less than optimal under extreme conditions.

The impact on facility speed is small but positive, particularly for urban arterials. Stops overall are reduced by 2.7%. Stops are reduced along urban arterial system, as expected, but freeway links also see a reduction in stops. This may be indicative of increased travel load being borne by the arterial system, freeing up capacity on the freeways.

Table ES-4. Energy and Emissions Impacts, ATMS Experiment

Measure per Average AM Peak Period	Baseline	ATMS	Change	% Change
Fuel Consumption (l)	354,600	355,600	+1,000	+0.3% (NS)
HC Emissions (kg)	390.0	392.6	+2.6	+0.7% (NS)
CO Emissions (kg)	7043	7116	+73	+1.0% (NS)
NOx Emissions (kg)	846.2	850.2	+4.0	+0.5% (NS)

(NS) = not statistically significant vs. baseline at 90% confidence level

<u>Energy and Emissions Impacts</u>: A reduction in overall stops does not fully compensate for the 0.4% increase in subarea travel in the emissions analysis (Table ES-4). Overall, small increases

are indicated for fuel consumption and the three pollutants, but none of these increases are statistically significant when compared with the inherent randomness in the simulation.

Safety Impacts: Overall, the expected number of crashes decreased by 2.5%. The total number of fatal crashes projected over a ten-year period decreased by 1.1%, from 114.9 to 113.7. This reduction can be attributed to a shift from lower-speed travel (in particular for ATMS from the 32-40 kph range) to higher-speed travel (60-80 kph range).

IMS Experiment: Hypothesis, Controls and Findings

Hypothesis: A reduction in incident duration improves throughput and efficiency.

Experimental Controls: In this experiment, we reflect system level impacts resulting from the ability of highway patrol, WSDOT, and emergency medical service providers to coordinate their response to incidents. Relevant MMDI projects include Regional Video Sharing, Incident Information Capture, On-Scene Incident Video, and Emergency Operations Center Coordination. Reaction to an incident may be characterized by detection time, response time (time to getting the first unit to the incident site), and time-to-removal. In this experiment, we assume that there is no change from the current incident detection and response times of 4 and 6 minutes, respectively. However, we do assume some reduction in incident duration because of increased coordination among responding agencies. Estimates in Seattle of such impacts are not currently available; however, we attempted to estimate this impact by using data from a similar study in Houston where a 25% reduction in incident duration was reported. Given the incremental nature of the MMDI-related enhancements relative to the existing incident management infrastructure in Seattle, a more conservative 12.5% incident duration reduction was selected for evaluation. These reductions were implemented only for accidents occurring along SR99 and I-5.

Network Efficiency Impacts: IMS impacts are concentrated in scenarios that have major incidents or large numbers of accidents on SR99 and I-5. Eighty percent of the delay reduction from improved IMS occurs in scenarios with a combined probability of roughly 5%. The timing and location of incidents are critical in terms of IMS effectiveness. Major disruptions on the freeway when combined with heavy demand or snow show the most significant impact. Benefit is highly concentrated, even in the freeway incident cases, among users traveling particular facilities at particular times. One may characterize IMS impacts as the most highly concentrated (of the three sensitivity analyses) in terms of geography, trip timing, and scenario. At the 12.5% incident duration reduction, however, no significant impacts can be measured for overall annualized delay or other impact measures. A sensitivity analysis at the 25% blockage duration reduction level showed an annualized reduction of roughly 90 vehicle-hours of delay per AM peak period.

Energy and Emissions Impacts: Small changes in energy and emissions impacts are indicated for the IMS experiment. These changes are so small, however, that they are statistically too small to measure over the inherent randomness in the simulation.

Safety Impacts: Small system-level changes in travel speed result in safety impacts that cannot be measured over the inherent randomness in the simulation.

Arterial Data for ATIS Integration Experiment: Hypothesis, Controls and Findings

Hypothesis: The provision of arterial travel time estimates from SR99 and SR522 to ATIS users improves overall system efficiency.

Experimental Controls: This experiment models the integration of data from arterial loop detectors along SR99 and SR522 into the freeway-based ATIS available on the WSDOT website and other media. The baseline case assumptions remain the same as in the ATIS and ATMS experiments. No changes to existing traffic signal control along the two arterials are modeled, the only change is that users of ATIS may now consider real-time estimates of congestion on the two arterial routes in addition to I-5 conditions when making travel decisions. We assume the arterial data is updated every 15 minutes and is provided as a combined estimate of both link travel time and intersection delay.

Table ES-5. System Efficiency Impacts, Arterial Data for ATIS Experiment

Measure per Average AM Peak Period, North Corridor Subarea	Baseline	ATIS (+ Arterials)	Change	% Change
Vehicle-Hours of Delay	17,879	17,308	-571	-3.4%
Vehicle Throughput	209,372	209,575	+203	+0.1%
Coefficient of Trip Time Variation	.242	.239	-.003	-1.2%
Vehicle-Km of Travel	3,438,000	3,443,000	+5,000	+0.2%
Total Number of Stops	1,200,000	1,134,000	-66,000	-5.5%

Network Efficiency Impacts: The provision of arterial data roughly triples the overall system impact of ATIS in the North Corridor. Vehicle hours of delay are reduced by 571, a 3.4% decrease. Vehicle throughput is also higher, with an additional 203 vehicles successfully traversing the network on average each AM peak period. Trip time reliability is improved by 1.2%. Total travel is slightly increased, while stops are decreased by 5.5%.

Overall, it is clear that the provision of travel time estimates on the primary alternatives to I-5 in the North Corridor allows travelers to make more efficient route choice decisions. Patterns of use are also changed – total freeway to arterial diversion decreases when the arterial data appears in ATIS. This is because unwarranted diversions away from the freeway are reduced given that travelers now have a more current accurate estimate of arterial performance.

Table ES-6. Energy and Emissions Impacts, Arterial Data for ATIS Experiment

Measure per Average AM Peak Period	Baseline	ATIS (+ Arterials)	Change	% Change
Fuel Consumption (l)	354,620	351,730	-2,890	-0.8%
HC Emissions (kg)	390.0	382.8	-7.2	-1.9%
CO Emissions (kg)	7043	6830	-88	-3.0%
NOx Emissions (kg)	846.2	820.6	-25.6	-3.0%

Energy and Emissions Impacts: A 5.5% drop in number of stops under relatively stable total travel results in across the board improvements in energy efficiency and emissions reductions. Most notably, a 3.0% reduction in total CO emissions and total NOx emissions is indicated, primarily the result of a reduction in high-speed stops. A smaller reduction is indicated for HC, while overall fuel consumption drops by 0.8%.

Safety Impacts: Overall, the expected number of crashes decreased by 1.0%. The total number of fatal crashes projected over a ten-year period decreased by 0.3%, from 114.9 to 114.6.

Enhanced ITS Alternatives Analysis: Hypothesis, Controls and Findings

Hypothesis: Implementing an integrated deployment combining ATIS and ATMS technologies improves system throughput and efficiency.

Experimental Controls: The Enhanced ITS Alternative is a prospective integrated deployment of the improvements made as a part of the ATIS and ATMS experiments. Thus, it features an improved signal coordination system on SR99 and SR522, and a user base of 6% of travelers using ATIS that includes both I-5 freeway congestion estimates as well as travel time estimates along SR99 and SR522. However, this alternatives analysis is different than the simulation experiments discussed thus far because it involves the utilization of regional and subarea modeling in the PRUEVIIN framework. With the presence of the regional model in the analysis, changes in corridor travel demand in response to system capacity improvements can be assessed. In this analysis, we have isolated the impacts of the Enhanced ITS alternative with and without changes to regional travel demand.

Regional Travel Impacts: Overall, the impacts of the improvements at the regional level are logical, but relatively small. A slight shift from transit to the auto modes (-0.14%) is seen due to the improvements. Trips are longer (+0.4%) and have improved speeds (+0.6%). There is also a diversion of roughly 1,000 trips during the AM peak period to the simulation area, primarily from the travel on I-405 to the east of the North Corridor. Thus, the travel demand with feedback seen in the subarea is 0.4% higher than without feedback, and these new trips introduced into the subarea are longer on average than in the baseline demand case.

Subarea Network Efficiency Impacts: A summary of network efficiency impacts associated with the Enhanced ITS alternative with feedback to the regional model is presented in Table ES-7. The integrated deployment reduces overall subarea delay by 6.1% while carrying additional 1,300 vehicles in the AM peak period. Subarea travel increases by 0.9% although total number of stops drops by 4.7%.

Table ES-7. System Efficiency Impacts, Enhanced ITS Experiment
(with feedback to regional model)

Measure per Average AM Peak Period, North Corridor Subarea	Baseline	Enh. ITS (with feedback)	Change	% Change
Vehicle-Hours of Delay	17,879	16,893	-986	-6.1%
Vehicle Throughput	209,372	210,704	+1,331	+0.7%
Coefficient of Trip Time Variation	.242	.241	-.001	-0.4%
Vehicle-Km of Travel	3,438,000	3,487,000	+49,000	+1.4%
Total Number of Stops	1,200,000	1,149,000	-51,000	-4.3%

Table ES-8. System Efficiency Impacts, Enhanced ITS Experiment
(no feedback to regional model)

Measure per Average AM Peak Period, North Corridor Subarea	Baseline	Enh. ITS (no feedback)	Change	% Change
Vehicle-Hours of Delay	17,879	16,534	-1,345	-7.8%
Vehicle Throughput	209,372	210,007	+635	+0.3%
Coefficient of Trip Time Variation	.242	.233	-.008	-3.3%
Vehicle-Km of Travel	3,438,000	3,453,000	+15,000	+0.4%
Total Number of Stops	1,200,000	1,144,000	-55,000	-4.6%

The impact of regional feedback can be seen by comparing these results against the Enhanced ITS analysis performed under baseline travel demand in Table ES-8. In this case, higher delay reduction is seen (7.8%) as well as a reduction in trip time variability (3.3%), while the increase in throughput is lower (0.3%). This result stems from the fact that under feedback to the regional model, the improvements in the subarea attract new demand to the improved facilities. The new demand raises the overall level of congestion in the network, resulting in increased throughput but lower delay reduction and higher trip time variability.

Table ES-9. Subarea Energy and Emissions Impacts, Enhanced ITS Experiment
(with feedback to regional model)

Measure per Average AM Peak Period	Baseline	Enh. ITS (w/feedback)	Change	% Change
Fuel Consumption (l)	354,620	355,130	+510	+0.1% (NS)
HC Emissions (kg)	390.0	387.8	-2.2	-0.6% (NS)
CO Emissions (kg)	7043	6955	-88	-1.3% (NS)
NOx Emissions (kg)	846.2	835.7	-10.5	-1.3%

(NS) = not statistically significant vs. baseline at 90% confidence level

Subarea Energy and Emissions Impacts: The combination of more subarea travel and reduced stops results in a mixed bag of energy and emissions impacts. A statistically significant reduction in NOx emissions is indicated (-1.3%). HC and CO emissions are also lower, although these changes do not meet the 90% confidence interval for statistical significance. Although total fuel consumption is slightly higher, tracking an increase in total travel, average vehicle fuel economy (miles per gallon) improves by 1.3% to 23.5 mpg from 23.2 in the Baseline case.

Safety Impacts: Overall, the expected number of crashes decreases by 1.9%. Total fatal crashes expected over a ten-year period in the corridor increases 0.8% from 114.9 to 115.8. This increase is a result of both higher travel speed and increased travel in the corridor. Fatal accident rates per million vehicle kilometers traveled actually decline 0.6%.

Discussion and Conclusions

A key feature of the MMDI evaluation effort is in the identification of benefits associated with the deployment of integrated ITS, rather than stove-pipe functional or jurisdictional systems. The Seattle MMDI deployment has examples of both functional (utilization of arterial congestion data for both traffic signal control and ATIS) and jurisdictional cooperation (traffic signal coordination along major arterial corridors). Based on the full range of assessments conducted in this study, some key observations can be made on the impact of integrated ITS systems.

The *benefit of jurisdictional cooperation for signal control* is illustrated in the impacts associated with the ATMS experiment. The combination of better data on arterial queue length in the AM peak and the coordination of signals at variable progression speeds (both major and minor) is projected to reduce system-wide delay by 7%. The subarea model available for this effort and the experiments performed are not detailed enough to produce a traffic signal timing plan that can be directly implemented in the field. However, for traffic engineers in Seattle, Lynnwood and other jurisdictions in the North Corridor, the 7% delay reduction provides a quantitative estimate of potential benefit that can be used in prioritizing the development of a detailed plan for SR99 or SR522. Further, the delay reduction figure demonstrates to local jurisdictions that cooperation on timing plans has a quantifiable potential benefit, bolstering an argument that was heretofore conjecture.

Another useful observation concerning jurisdictional cooperation for signal control is that although well-timed plans are generally beneficial, the range of conditions (particularly the combination of weather and travel demand variations) seen in the North Corridor cannot always be satisfied with a single fixed plan. A case can be made, therefore, that *even more benefit could reasonably be expected if alternative plans could be implemented* for particular observed conditions. For example, a coordinated plan with shorter cycle lengths and faster progression speeds could be developed for light demand conditions. This signal control strategy would require cooperation between jurisdictions on a day-to-day basis to select the appropriate coordinated plan from a list of approved alternatives.

ATIS has largest impact during conditions associated with the worst congestion: heavy demand, major accidents or extreme weather. Eighty percent of the total delay reduction from ATIS is accounted for a set of scenarios with a combined probability of 28%. This set is composed of scenarios with either heavy demand, a major accident, extreme weather, or a combination of these factors. ATIS effectiveness under these conditions is reflected in its impact on travel time variability. In the ATIS experiment an average of 260 hours of vehicle delay is eliminated each AM peak, compared with 1,218 hours in the ATMS experiment. However, the ATIS impact on annual travel time variability (-2.5%) is larger than the ATMS experiment (-2.1%).

Integrating arterial congestion data with freeway-based ATIS clearly improves the effective utilization of ATIS by the travelers modeled in the North Corridor. The delay reduction associated with a 6% usage rate in the AM peak more than doubles from 1.5% to 3.4% when congestion data on parallel arterial facilities (SR99 and SR522) is made available to ATIS. User delay reduction is similarly enhanced. This larger impact should be interpreted understanding the focus of the evaluation network on corridor-specific travel. Travelers planning for long trips from the extreme north to south within the Puget Sound region, e.g. Everett to Tacoma, have freeway-to-freeway alternatives (I-5 vs. I-405) that are not represented by the current North Corridor model. The range of choices is limited to the corridor level (SR99 vs. I-5), so we expect some underestimation of benefit for these types of trips. Providing arterial congestion data is likely more useful for the inter-corridor, moderate length trip maker (e.g., Edmonds to the University of Washington campus) than for the long regional trip maker.

Another goal for MMDI evaluation is to *quantify the overall system impacts of integrated ITS compared with isolated deployments of ITS functional components*. An examination of the conditions where benefit can be expected from each functional component is illustrative of how these functional components may be interacting. For example, IMS and ATIS have highest impact in many of the same situations, primarily corresponding to freeway incident cases and extreme weather cases. Traffic signal control impacts are insensitive to incidents and have highest impact where the ratio of travel demand to roadway capacity is close to expectation. In scenarios where impact by functional component overlaps, impacts from adding in a new functional component is diluted by the simple fact that there is less delay to eliminated.

At the corridor level, projected energy and emission impacts associated with MMDI-related ITS enhancements are small and indeterminate. Overall energy consumption in the corridor is projected to increase as additional travel demand is drawn into the more efficiently operating corridor roadway system. However, fuel economy (on a miles-per-gallon basis) within the corridor is slightly improved because of reduced stop-and-go traffic conditions. Overall emissions of pollutants (HC, CO, and NOx) are generally slightly lower, but in many cases these reductions are too small to be statistically significant. A key observation is that the smoother traffic flow (defined in terms of stops/vehicle-km) associated with MMDI-related ITS enhancements improve corridor throughput without an increase in overall emissions.

Projected corridor-level safety impacts are small but positive. Using an analysis of travel speed and crash rates, the MMDI-related ITS enhancements generally produce slightly higher travel speeds and hence less frequent crashes. Although the proportion of all crashes that involve at least one fatality increases with travel speed, the overall number of fatal crashes typically remains steady because of the overall reduction in total crashes.

Another observation that can be made is that the impacts associated with the Enhanced ITS alternative are relatively small when compared with the impacts projected for fully integrated end-state ITS deployments like the one tested in the Seattle 2020 analysis. The difference in impact is reflective of the significant difference in how much ITS is deployed in each case. For example, the 2020 ITS Rich alternative features comprehensive adaptive ATMS arterial control, integrated freeway/arterial surveillance supplemented by probe vehicles for ATIS, and higher usage rates for advanced pre-trip and en-route traveler information services. The Enhanced ITS alternative is best viewed as an evolutionary step towards such a fully integrated ITS deployment.